River and Watershed Conference
November 2003

Low-Impact Development Technology

A Comprehensive Innovative Stormwater Management Technology to Protect Both Aquatic Living Resources and Water Resources

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Low Impact Development (LID)

Stormwater Management

Ecosystem Based Functional Design

"Uniformly Distributed Small-scale Controls"

"Integration of Controls with Sites, Streets and Architecture "

*** Low Cost & Low Impacts ***

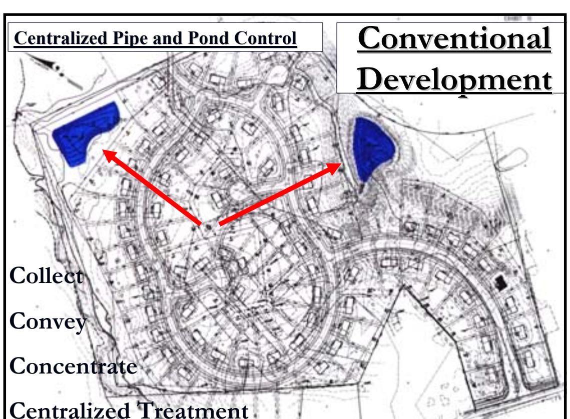
Prince George's County, MD

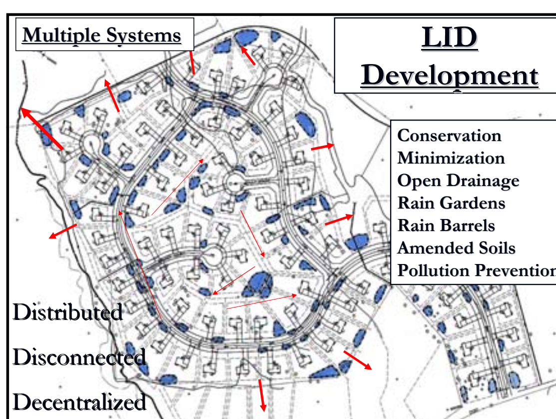
LID National Design Manual 1999

"Centralized versus Decentralized Controls"

Low Impact Development Technology Overview

- **New Philosophy**
  - Maintaining the Functional Relationship Between Terrestrial and Aquatic Ecosystems
- **New Principles**
  - Decentralized / Source Control
  - Distributed / Multi-functional / Multi-beneficial
- **New and Old Practices**
  - Retain / Detain / Filter / Infiltrate / Treat / Prevent / Use
- **New Process**
  - Conserve / Minimize / Timing / Integrate Practices / Prevent





Water Resources – Why LID?

- Water Supply
- Wastewater
- Stormwater
  - Flood Control
  - Ecological Health
  - Human Use
  - Regulations

Limitations of Conventional Stormwater Approaches

- Economics
  - Cost of Maintaining a Growing / Aging Infrastructure
- New Objectives (Public Health / Ecological)
  - Source Water, CSO's, Living Resources / Streams
  - Regulations
    - NPDES / TMDL's / ESA

Limitations of Conventional Stormwater Approaches

- Technology Gaps
  - Not an anti-degradation strategy
  - Allows hydrodynamic modifications
  - Allows continued stream degradation
  - Allows cumulative impacts
  - Limited use for urban retrofit
  - Unsustainable maintenance burdens

Ecosystem Protection

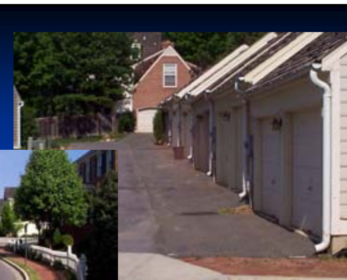
Protecting or restoring the natural functions, structures, and species composition of an ecosystem, recognizing that all components are interrelated. -- U.S. Fish and Wildlife Service

Apply ecology, science and engineering to ensure homeostasis between the terrestrial and aquatic ecosystems for long-term sustainability.

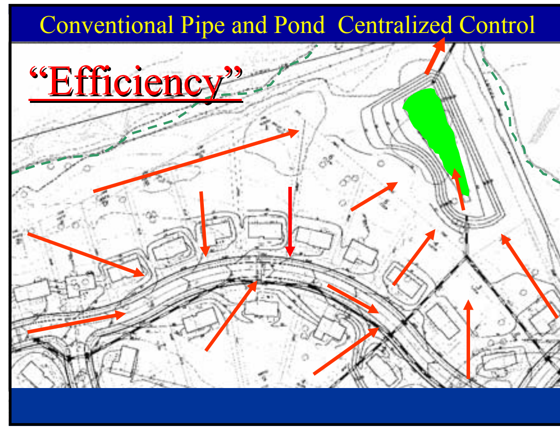
Natural Conditions

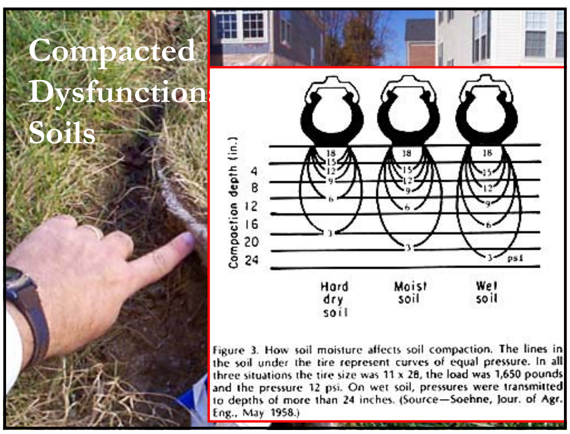
Developed Conditions

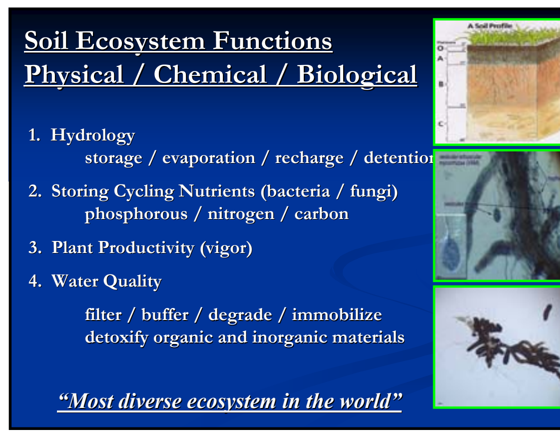
Hydrologically Connected



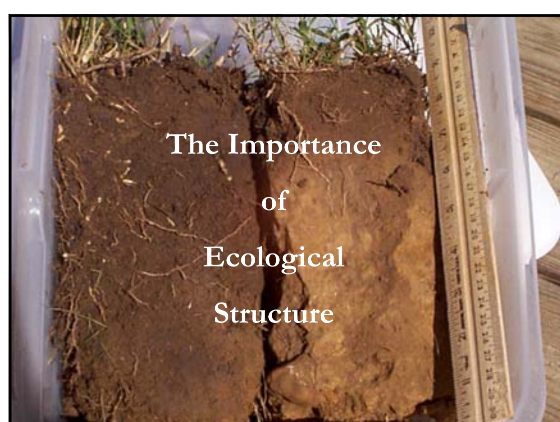
Ecologically Dysfunctional

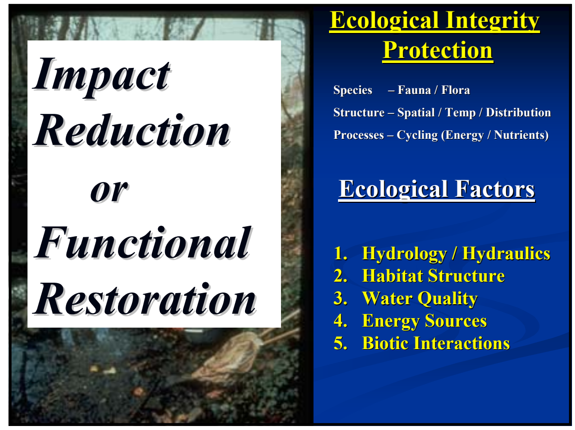

Conventional Pipe and Pond Centralized Control
"Efficiency"

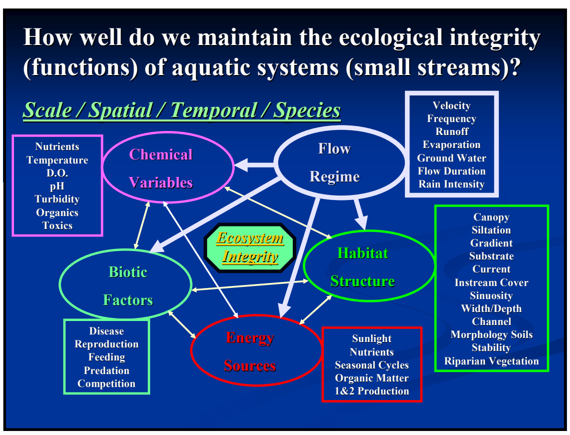

Compacted
Dysfunctional
Soils
Compaction depth (in.)
4
8
12
16
20
24
psi
Hard dry soil
Moist soil
Wet soil
Figure 3. How soil moisture affects soil compaction. The lines in the soil under the tire represent curves of equal pressure. In all three situations the tire size was 11 x 28, the load was 1,650 pounds and the pressure 12 psi. On wet soil, pressures were transmitted to depths of more than 24 inches. (Source—Soehne, Jour. of Agr. Eng., May 1958.)

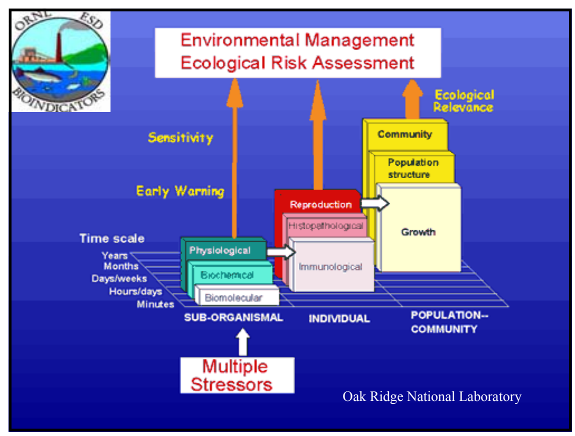

Soil Ecosystem Functions
Physical / Chemical / Biological
1. Hydrology
storage / evaporation / recharge / detention
2. Storing Cycling Nutrients (bacteria / fungi)
phosphorous / nitrogen / carbon
3. Plant Productivity (vigor)
4. Water Quality
filter / buffer / degrade / immobilize
detoxify organic and inorganic materials
"Most diverse ecosystem in the world"

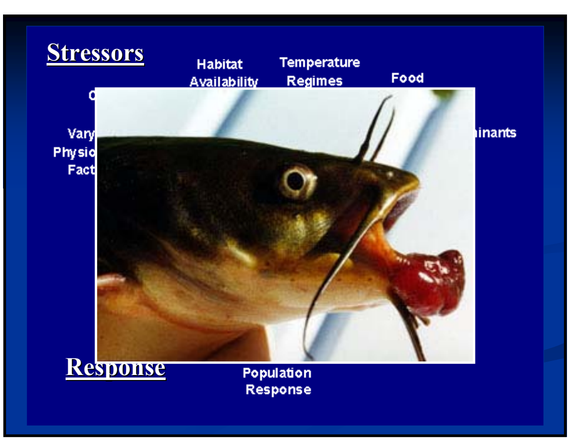

Ecological Structure – It's Alive!
IT'S
NOT
DIRT
Soil / Plant / Microbe Complex
A Dynamic Living Ecosystem Cycling Nutrients, Chemicals Water and Energy
Synergistic Relationship
Plants / Bacteria / Protozoa
Fungus / Worms* / insects /
Mammals

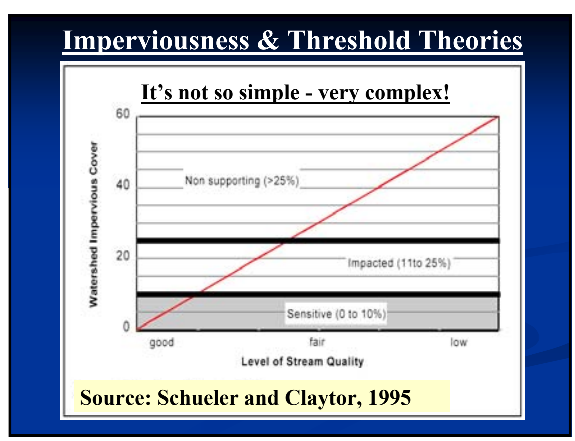

The Importance
of
Ecological
Structure


Impact Reduction or Functional Restoration
Ecological Integrity Protection
Species – Fauna / Flora
Structure – Spatial / Temp / Distribution
Processes – Cycling (Energy / Nutrients)
Ecological Factors
1. Hydrology / Hydraulics
2. Habitat Structure
3. Water Quality
4. Energy Sources
5. Biotic Interactions

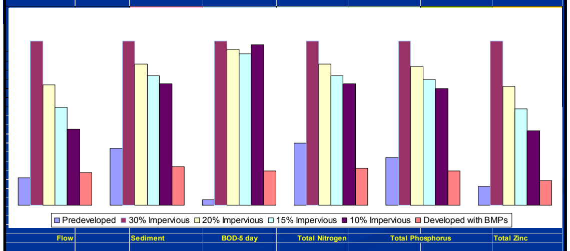

How well do we maintain the ecological integrity (functions) of aquatic systems (small streams)?
Scale / Spatial / Temporal / Species
Nutrients Temperature D.O. pH Turbidity Organics Toxics
Chemical Variables
Flow Regime
Velocity Frequency Runoff Evaporation Ground Water Flow Duration Rain Intensity
Ecosystem Integrity
Habitat Structure
Canopy Siltation Gradient Substrate Current Instream Cover Sinuosity Width/Depth Channel Morphology Soils Stability Riparian Vegetation
Biotic Factors
Disease Reproduction Feeding Predation Competition
Energy Sources
Sunlight Nutrients Seasonal Cycles Organic Matter 1&2 Production

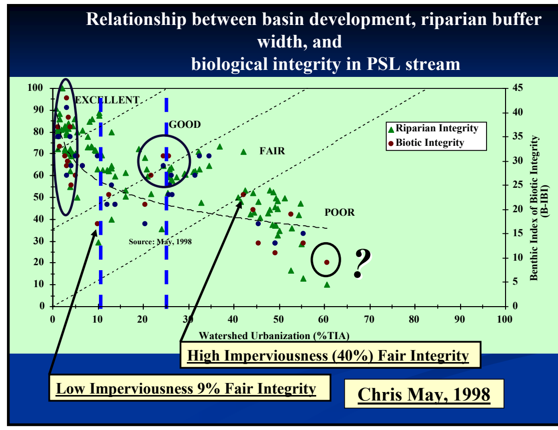

ORNL ESD BIOINDICATORS
Environmental Management
Ecological Risk Assessment
Sensitivity
Early Warning
Ecological Relevance
Community
Population structure
Reproduction
Histopathological
Growth
Immunological
Physiological
Biochemical
Biomolecular
Time scale
Years Months Days/weeks Hours/days Minutes
SUB-ORGANISMAL
INDIVIDUAL
POPULATION--COMMUNITY
Multiple Stressors
Oak Ridge National Laboratory


Stressors
Habitat Availability
Temperature Regimes
Food
Response
Population Response

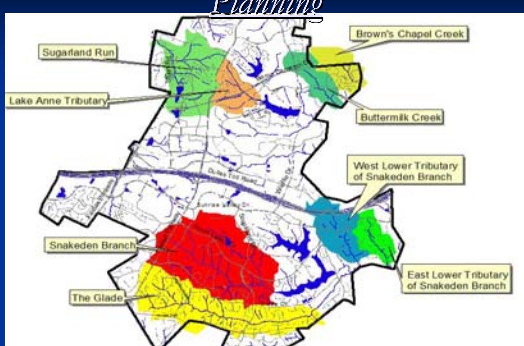

Imperviousness & Threshold Theories
It's not so simple - very complex!
Watershed Impervious Cover
60
40
20
0
Non supporting (>25%)
Impacted (11to 25%)
Sensitive (0 to 10%)
good
fair
low
Level of Stream Quality
Source: Schueler and Claytor, 1995

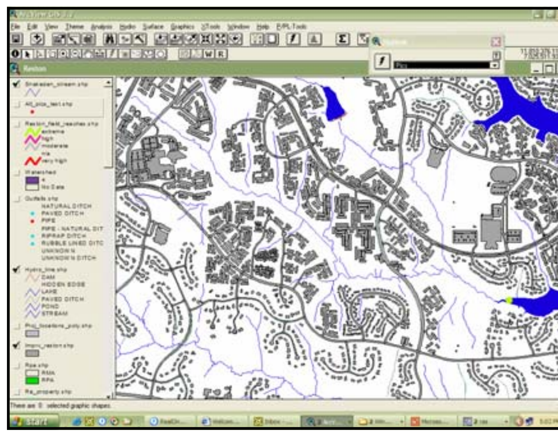
Indicator	Units	Predeveloped	Developed with 30% Impervious no BMPs	Developed with 20% Impervious no BMPs	Developed with 15% Impervious no BMPs	Developed with 10% Impervious no BMPs	Developed with LID BMPs
Flow	ft3/yr	37,346	225,135	164,371	133,989	104,157	44,727
Sediment	Tons/yr	0.644	1.872	1.607	1.474	1.384	0.441
BOD-5 day	lb/yr	5.15	165.70	156.85	152.42	161.40	34.42
Total Nitrogen	lb/yr	9.27	24.58	21.11	19.37	18.12	5.51
Total Phosphorus	lb/yr	1.029	3.550	2.994	2.715	2.522	0.741
Total Zinc	lb/yr	0.309	2.750	1.989	1.608	1.243	0.412

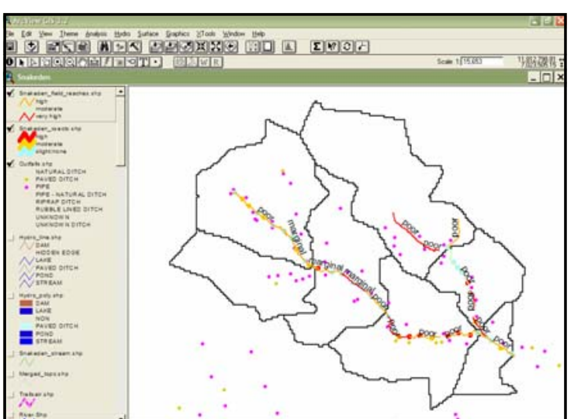




Reston Watershed Management Planning



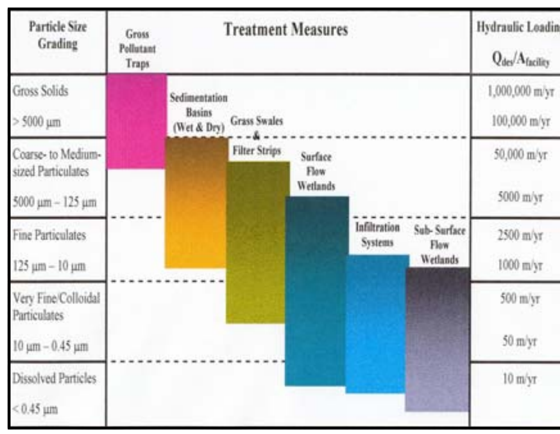


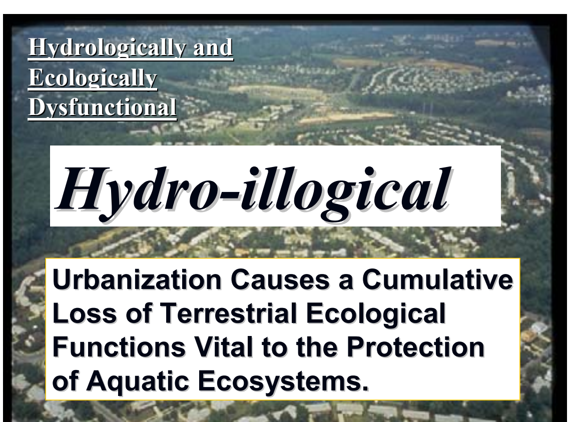


Wet Weather Monitoring

Maximum Concentrations at In-stream Stations

Parameter	EPA Criteria chronic	EPA Criteria acute	L. Beaver-dam Cr.	Western Branch	Collington Branch
Cadmium (ug/l)	1.1	3.9	40	1.0	10
Copper (ug/l)	12	18	470	30	57
Lead (ug/l)	3.2	83	1700	66	34
Zinc (ug/l)	110	120	5400	160	330
Total P (mg/l)	0.1		3.2	0.74	3.4
TKN (mg/l)			6.0	7.2	9.9
Nitrate (mg/l)	10		2.5	1.0	1.8
BOD (mg/l)	7		71	57	27
TSS (mg/l)	500		4800	910	2500
Fecal Coliform (org/100 ml)	200		220000	13000	17000
Oil/Grease (mg/l)	--		7	BDL	BDL





How Does LID Maintain or Restore The Hydrologic Regime?

- Creative ways to:
  - Maintain / Restore Storage Volume
    - interception, depression, channel
  - Maintain / Restore Infiltration Volume
  - Maintain / Restore Evaporation Volume
  - Maintain / Restore Runoff Volume
  - Maintain Flow Paths
- Engineer a site to mimic the natural water cycle functions / relationships

LID Basics

Principles

Practices

Process

Key LID Principles "Volume"

"Hydrology as the Organizing Principle "

- Unique Watershed Design
  - Match Initial Abstraction Volume
  - Mimic Water Balance
- Uniform Distribution of Small-scale Controls
- Cumulative Impacts of Multiple Systems
  - filter / detain / retain / use / recharge / evaporate
- Decentralized / Disconnection
- Multifunctional Multipurpose Landscaping & Architecture
- Prevention

Defining LID Technology

Major Components

1. Conservation (Watershed and Site Level)
2. Minimization (Site Level)
3. Strategic Timing (Watershed and Site Level)
4. Integrated Management Practices (Site Level)
   Retain / Detain / Filter / Recharge / Use
5. Pollution Prevention
   Traditional Approaches

1. Conservation Plans / Regulations

- Local Watershed and Conservation Plans
  - Forest (Contiguous and Interior Habitat)
  - Streams (Corridors)
  - Soils
  - Recharge Areas
  - Wetlands
  - Habitats
  - Step Slopes
  - Buffers
  - Critical Areas
  - Parks
  - Scenic Areas
  - Trails

2. Minimize Impacts

- Minimize clearing
- Minimize grading
- Save A and B soils
- Limit lot disturbance
- Alternative Surfaces
- Reforestation
- Disconnect
- Reduce pipes, curb and gutters
- Reduce impervious surfaces

3. Maintain Time of Concentration

- Open Drainage
- Use green space
- Flatten slopes
- Disperse drainage
- Lengthen flow paths
- Save headwater areas
- Vegetative swales
- Maintain natural flow paths
- Increase distance from streams
- Maximize sheet flow

4. Storage, Detention & Filtration "LID IMP's"

- Uniform Distribution of Source Controls
  - Open drainage swales
  - Rain Gardens / Bioretention
  - Smaller pipes and culverts
  - Small inlets
  - Depression storage
  - Infiltration
  - Rooftop storage
  - Pipe storage
  - Street storage
  - Rain Water Use
  - Soil Amendments*

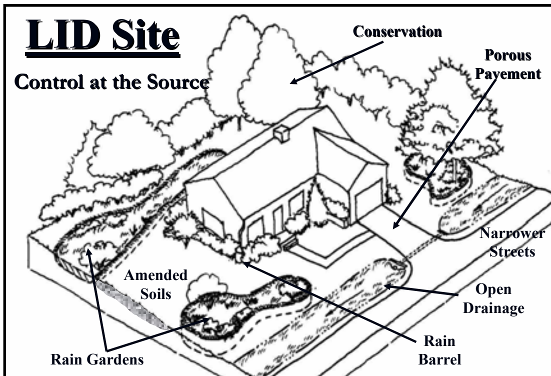
5. Pollution Prevention

30 - 40% Reduction in N&P
Kettering Demonstration Project

- Maintenance
- Proper use, handling and disposal
  - Individuals
    - Lawn / car / hazardous wastes / reporting / recycling
  - Industry
    - Good house keeping / proper disposal / reuse / spills
  - Business
    - Alternative products / Product liability

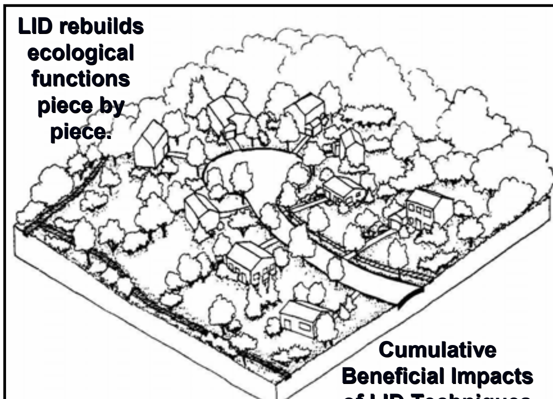
LID Site

Control at the Source



Create a Hydrologically Functional Lot

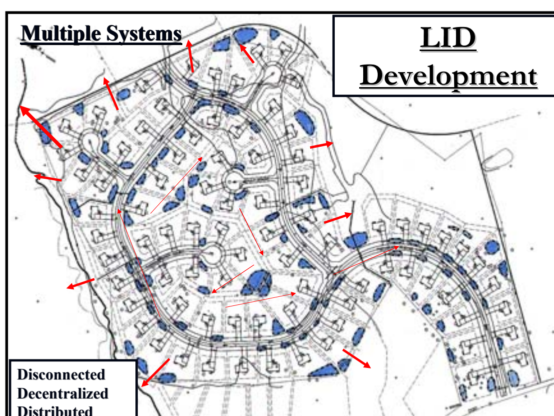
LID rebuilds ecological functions piece by piece.



Cumulative Beneficial Impacts of LID Techniques

LID Development

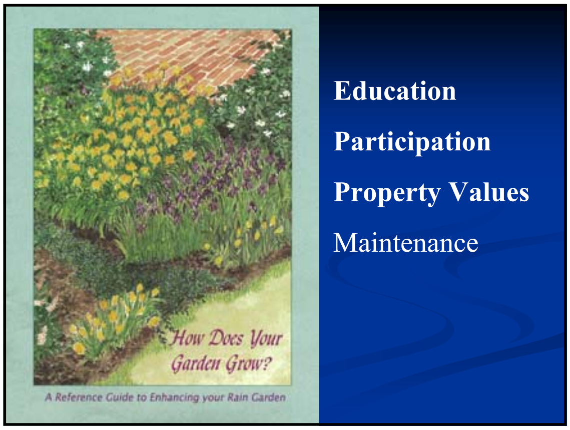
Multiple Systems

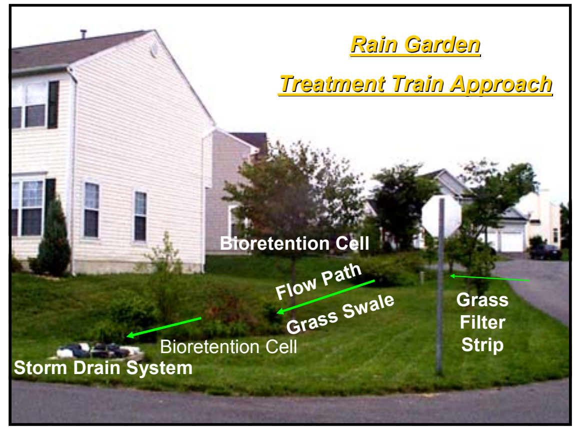


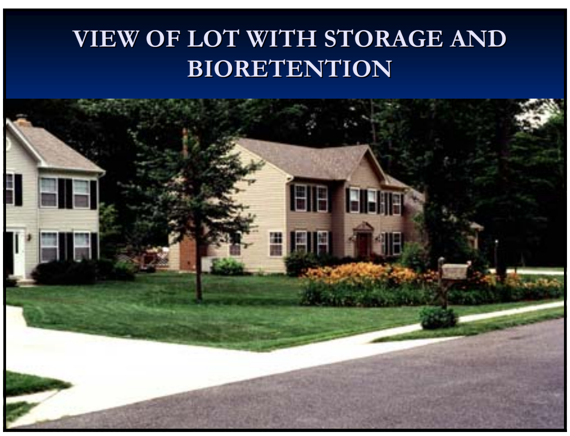
Disconnected
Decentralized
Distributed


Rain
Gardens
Typical Landscape Maintenance Practices


Rain
Gardens


Education
Participation
Property Values
Maintenance
How Does Your Garden Grow?
A Reference Guide to Enhancing your Rain Garden


Rain Garden
Treatment Train Approach
Bioretention Cell
Flow Path
Grass Swale
Grass Filter Strip
Bioretention Cell
Storm Drain System


VIEW OF LOT WITH STORAGE AND BIORETENTION

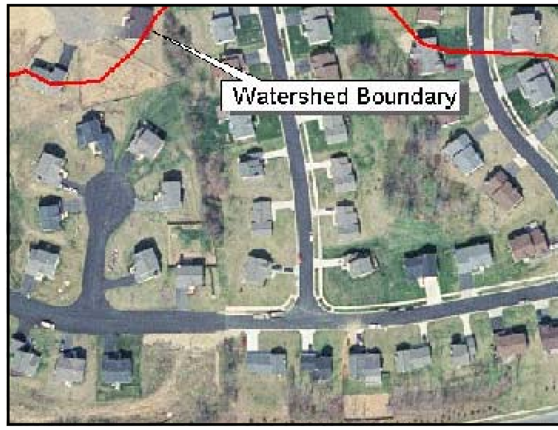

Rain is Resource
Capture & Use
Toilet Flushing
Car washing
Irrigation
Mixing / Washing
Gardening
Recharge
Benefits
Reduce Demand
Self-sufficiency
Save Money


Caring For Your Car Without Harming The Environment
Rain Gardens
Green Lawns
The Smart Way
pollution prevention

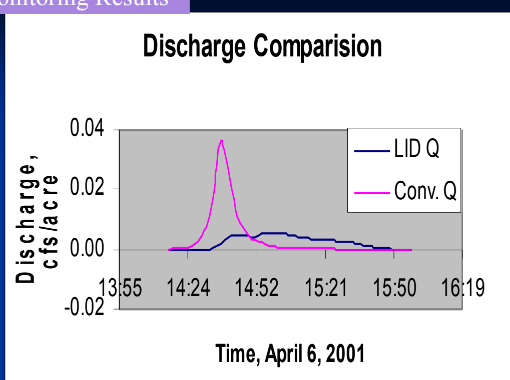
LID Practices (No Limit!)

"Creative Techniques to Treat,Use, Store, Retain, Detain and Recharge"

- Bioretention / Rain Gardens*
- Strategic Grading*
- Site Finger Printing
- Conservation*
- Flatter Wider Swales
- Amended Soils*
- Long Flow Paths
- Tree / Shrub Depression
- Turf Depression
- Landscape Island Storage
- Rooftop Detention /Retention
- Disconnection*
- Parking Lot / Street Storage
- Smaller Culverts, Pipes & Inlets
- Alternative Surfaces
- Reduce Impervious Surface
- Surface Roughness Technology
- Rain Barrels / Cisterns / Water Use*
- Catch Basins / Seepage Pits
- Sidewalk Storage
- Vegetative Swales, Buffers & Strips*
- Infiltration Swales & Trenches
- Eliminate Curb and Gutter
- Shoulder Vegetation
- Maximize Sheet flow
- Maintain Drainage Patterns
- Reforestation………………..
- Pollution Prevention…………..



Monitoring Results



Construction Cost Comparison

	Conventional	Low Impact
Grading/Roads	**$569,698**	**$426,575**
Storm Drains	**$225,721**	**$132,558**
SWM Pond/Fees	**$260,858**	**$ 10,530**
Bioretention/Micro	**—**	**$175,000**
Total	$1,086,277	$744,663
Unit Cost	$14,679	$9,193
Lot Yield	74	81

"Technology can be a common ground for agreement by all parties if it does not increase costs and meets resource protection goals"

LID Technology is Supported by both the

National Association of Home Builders

and the

Natural Resources Defense Council

LID Urban Retrofit

"First Define Your Goals!"

Water Quality

Water Supply

Fisheries

Recreational Use

ESA

CSO

Flood Control

Urban LID Lot Level Control Opportunities

- Roofs
- Buildings
- Down Spouts
- Yards
- Sidewalks
- Parking Lots
- Landscape Areas
- Open space
- Amended Soils

Multifunctional Infrastructure

Retention

Detention

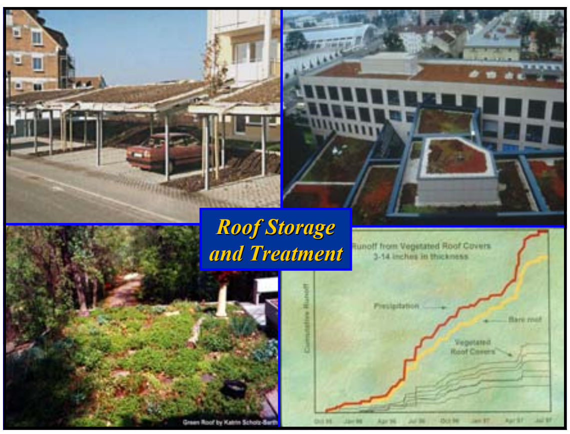
Filtration

Infiltration

Timing

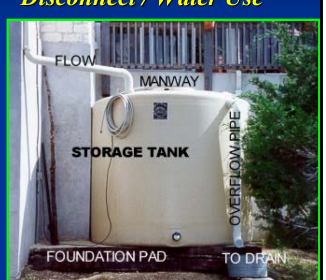
Water Use

Prevention



Buildings Design

Downspouts Disconnect / Water Use



Tzu Chi Hospital

Treatment System and Rainwater Tanks at Hospital and Schools

This foundation uses more than 10,000 tons of rainwater per year and is expanding its rainwater catchment system to integrate with the grey water system.


CHESAPEAKE BAY FOUNDATION
Save the Bay
• Rainwater Capture and Use
• Rain Gardens
• Porous pavements


Rain Barrels

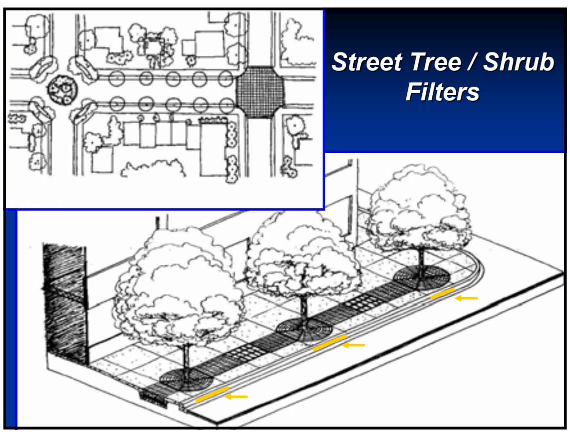

Weep Wall Filter


Urban Canopy
Multiple Benefits
* Reduce Stormwater Runoff
* Improve Air Quality
* Reduce Energy Consumption
* Reduce Urban Heat Island
* Carbon Storage
* Habitat Value


NORTHWESTERN HIGH SCHOOL
7000 ADELPHI ROAD


MAY 18 2001
Buckman Heights courtyard with infiltration garden


Rain Gardens
MAY 21 2001


Street Tree / Shrub Filters


Seattle, WA
"SEA" Street
Street
Edge
Alternative
SEA Streets - After Construction
2nd Ave NW - NW 117th St to NW 120th St


Fat Street


After Completion - January 2001
SEA Program, City of Seattle

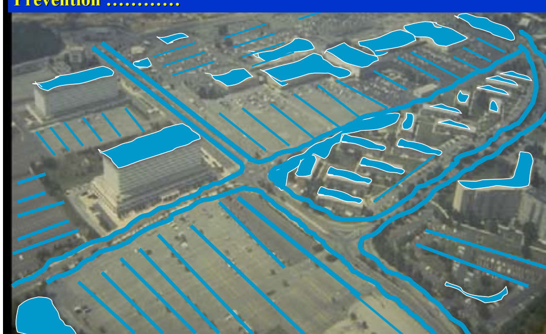

Skinny Street with Fat Person


Runoff Use / Filter
Cooling Systems
Herbert Dreiseitl - ww.dreiseitl.de

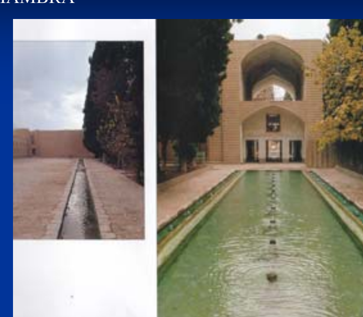
Rouge Plant - Future

Miller Road Frontage

Urban LID -- Rooftop Storage, Bioretention Landscaping, Parking Lot Storage, Longer Flow Paths, Swales, Water Use, Pollution Prevention …………



ALHAMBRA



ALHAMBRA

RAIN CHAINS

Multiple Benefits

- Replicate Predevelopment Water Balance
- Higher Pollutant Removal
- Increased Property Values
- Reduced Maintenance
- Energy Savings
- Reduced Thermal Pollution
- Reduced Safety Risks
- Increased Retrofit Opportunities
- Reduced Costs
- Less Destruction of the Wetland Habitat
- Technology / Science Based